INTRODUCTION

Aquaculture is farming of aquatic organisms not only fishes but also mollusks, crustaceans, and aquatic plants. It has been practiced in various part of the world for as long as 4,000 years ago. De Silva and Anderson (1995) reported that aquaculture was first practiced in mainland China since most of the first documentation on aquaculture was found in China. In addition, more than 2000 years ago the Japanese reared fishes in irrigation ditches (Ackefors *et al.*,1994).

Recently, fish landings from natural resources have reduced dramatically as development in sea fishing technologies, methods of seafood preservation and transportation improvement of. On the other hand, market demands have increased over the years as human population in the world and awareness on the nutritional advantages of fish protein increased. In 2020 for example, human population in the world is expected to reach 8.5 billion compared to 6.0 billion at present. Therefore, as countries seek for alternatives to meet the market demand, aquaculture and marineculture have been identified as possible solutions to this problem. For example, in 1998 aquaculture provided about 25% of the world's fish supply compared to 8% in 1984 (Kalyani, 2002). However, one of the main problem in aquaculture is high mortality of larvae that resulted in low production of fish culture. Application of a good broodstock and larval management programs are ways that can be used to overcome these problems and increase production of fish. A good management of broodstock will resulted in high quality of egg, sperm and larvae as well.

There are many factors have been identified as factors influencing egg quality and reproductive performance of fish female broodstock, such as nutrition in term of proteins, lipids, carbohydrates, vitamins and minerals; broodfish and environmental condition. Nutrition is a main factor that influence egg quality and reproductive performance of fish directly or indirectly.

Like terrestrial animals, fish needs protein, lipid, carbohydrate, minerals and vitamin for growing and maintaining their body. It has also been well known that the growth rate of broodfish is lower than that of larvae due to the fact that adult fish requires more energy for gonadal. development (Steffens, 1989).

Since the 1980s, increasing attention has been paid to the role of individual nutrient components in the diet of broodstock. The major group of feed components, including protein, fatty acid, and vitamin have been examined (Furuita *et al.*, 2001).

Besides the nutritional components, ratio size of broodstock can also affect egg and fry quality. In rainbow trout (*Salmo gairdneri*) for example, the eggs and fry produced by broodstock given a half daily ration (0.35% body weight per day) were significantly smaller (egg weight of 63.7 mg, and fry weight of 94.6 mg) than those of the full-ration of 0.7% body weight per day (82.9 mg egg weight and 105.1 mg fry weight) respectively, although broodstock ration size had no effect upon the amino acid composition of egg produced (Knox *et al.*,1988). Similarly, Ali and Wootton (1999) reported that female three-spined sticklebass *Gasterosteus aculatus,* fed with high rations (16% of BW per day) showed an increase in batch fecundity, and low ration (4% of BW per day) resulted in an increase in the number of days until the next spawning. Indeed, daily and seasonal rates of feeding of broodstock diets can affect to fecundity and egg size of fish (Carrillo *et al.*, 2000).

PROTEIN

Protein is an essential component of the cell nucleus, internal organs, brain, nerves and skin. Protein is large organic molecule that contain carbon, hydrogen, oxygen, nitrogen and often sulphur. The basic composition of most proteins are similar; C = 50-55%, H = 6-8%, O = 20-23%, N=15-18%, S=0-4%. The fundamental structural unit of the protein molecule is amino acid, which comprises of 20 naturally occurring types (Jobling, 1995). Tacon (1987) cited that enzymes which are proteins, play a critical role in cellular metabolism since all biochemical reaction depends on enzymes. Enzymes are essential for carbohydrate and lipid metabolism, for synthesis of tissue proteins and many important compounds, and protein can also form a source of energy for fish.

In general, amino acid can be classified into two groups ; the indispensable amino acids (arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, valine, and the dispensable amino acids (glycine, alanine, serine, tyrosine, cysteine, proline, hydroxyproline, aspartic acid, glutamic acid, and ornithine).

Indispensable amino acids are amino acids that cannot be synthesized within the animal body or at a rate insufficient to meet the physiological needs of the growing animal, and must therefore be supplied from the diet. On the other hand, dispensable amino acids are those that can be synthesized in the body from a suitable carbon source and other amino acids or simple compounds such as diammonium citrate, and consequently may not be supplied in ready made form in the diet (De Silva and Anderson, 1995).

Protein is a very expensive component in fish diets and accounts for as much as 40-70% of the aquaculture operational cost. Therefore, information of the optimum dietary protein requirement for the different fish species at different stages of growth is essential.

In broodstock, Eskalinen (1989) reported that the relative fecundity (the number of eggs produced per body weight of female) and egg size of Atlantic salmon was higher when they were fed 31% dietary protein level of semi moist feed. Similarly, Alhafedh *et al.* (1999) reported that the relative fecundity of Nile tilapia increased with increasing the dietary protein levels, and was significantly higher at 25-35% dietary protein than those fish fed 40-45% protein, but dietary protein levels between of 25% to 45% had no significant influence on egg size and weight. A similar result was reported by Cisse (1988), who reported that the highest spawning frequency and egg production were obtained from females fed with 30% protein compared to those of 20%, 25%, 35%, 40% or 50% dietary protein. Reduced fecundity have been reported in several fish species, where the cause could either be the influence of a nutrient imbalance on the brain-pituitary-gonad endocrine system or by the restriction in the availability of biochemical component for egg formation (Izquierdo *et al.*, 2001).

Dietary protein level influences puberty, oocyte development, spawning performance, and egg quality of Nile tilapia, *Oreachromis niloticus*. Nile tilapia fed a low protein diet (<17%) did not show oocyte maturation, while females fed 25% protein showed slower oocyte growth, and females fed >32% protein levels had early oocyte growth and maturation (Gunasekera *et al.*, 1995). Furthermore, Gunasekera *et al.* (1996b) later reported that Nile tilapia broodstock fed 20 and 35% protein diet produced a higher number of eggs per spawn (total fecundity) than those fed 10% protein, but egg size and relative fecundity did not differ significantly between the treatments. In sea bass, *Dicentrarchus labrax* the fecundity and reproductive performance were better at a higher dietary protein level of 51% (Cerda *et al.*,1994).

Wee and Tuan (1988) reported that the optimum dietary protein level for spawning *Oreochromis niloticus* was 35%. Broodstock fed with diets containing 20% protein were spawned lately, while other groups fed with higher dietary protein level of 27.5%, 35%, 42.5% and 50% spawned earlier. Moreover, the absolute and relative fecundities were found to be significantly higher in the fish fed with a 27.5% and 35% dietary protein than those fed with higher protein levels of 42.5 and 50%. However, high protein diets produced heavier and larger eggs at shorter spawning interval.

Proteins are ultimately degraded into amino acids that are utilized either as an energy source or for somatic protein synthesis. However, very little information is known about the specific amino acid requirements of the broodfish (Luquet and Watanabe, 1986). Dietary tryptophan, a precursor of the neurotransmitter serotonin, has been reported to positively affect gonad maturation in both males and females. Supplementation of 0.1% tryptophan in the diet of ayu (*Plecoglossu altivelis*) resulted in a significant increase in the serum testosterone level advancing the time of spermiation in males and induced maturation of females (Akiyama *et al*., 1996).

LIPID

Lipid is an important energy source in fish but with other important roles, such as being the transport medium for lipid-soluble compounds (e.g. some vitamins such as A, D, E, and K), as structural elements in cell membranes, and as precursors for a number of important biologically active compound (e.g. some hormone, pigments and growth factors) (Jobling, 1995).

Phospholipid especially determines cell membrane structure and fluidity (Zonneveld *et al*., 1991; Jobling, 1995), and dietary phospholipids are also reported to improve egg quality (Watanabe *et al.,* 1991). In addition, lipids in particular fatty acids have been shown to affect teleosts pituitary gland, which regulate gonadal hormone, and steroids sex levels (Cerda *et al*., 1994a; 1994b and Bruce *et al*., 1999). Indeed, Pustowka *et al*., (2000) reported that a 12% tallow oil (a highly saturated fatty acid) diet increased cholesterol and monounsaturated fatty acids level significantly in the spermatozoa plasma membranes compared to diets containing 12% herring, 12% menhaden or 12% safflower oils (high n-3, n-6 fatty acid), high level of cholesterol and mono-unsaturated fatty acids respectively in spermatozoa plasma membranes which in turn increased resistance to cryopreservation damage in rainbow trout.

Several researchers have emphasized the importance of lipid in broodfish nutrition. For example, Duray *et al.* (1994) reported that the elevation of dietary lipid level from 12% to 18% in broodstock diet of rabbitfish (*Siganus guttatus*) resulted in an increase in fecundity and hatching rate. Similarly, fecundity in gilthead seabream (*Sparus aurata*) was found to increase significantly with an increase in dietary n-3 HUFA level up to 1.6% (Fernandez-Palacios *et al*., 1995).

In addition, polyunsaturated fatty acid can also regulate eicosanoid production, particularly prostaglandins, which are involved in several reproduction processes, including the production of steroid hormone and gonadal development such as ovulation (Moore, 1995;

Mercure and Van Der Kraak. 1996).

Santiago and Rayes (1993) studied the effect of dietary lipid source on the reproductive performance and tissue lipids of Nile tilapia by feeding experimental diets containing 5% oil from different sources namely, cod liver oil, corn oil, soybean oil, coconut oil-based cooking oil, and combination of cod liver oil and corn oil. They found that cod liver oil (a sources n-3 fatty acid) resulted in poor reproductive performance, but the highest weight gain. Overall, seed production was found to be remarkably high for fish fed with soybean oil a source of 18:2, n-6 fatty acid.

CARBOHYDRATE

Carbohydrates are another important energy sources for terrestrial animals, but is not a primary energy source for aquatic animals since fish cannot digest it effectively (Steffens, 1989). However, there are no publications in the role of carbohydrate on the reproduction development of the fish.

VITAMIN AND MINERAL

Vitamins are essential for the maintenance of health and growth of fish, and act as cofactors or substrate in some metabolic reaction, and they are required in relative small amounts (De Silva and Anderson, 1995). Eleven water-soluble (ascorbic acid, myo-inositol, choline, thiamin, riboflavin, pyridoxine, pantothenic acid, biotin, niacin, folic acid, and cyanocobalamin) and four lipid-soluble vitamins (A, D, E, and K) are known to be required by fish (Jobling, 1995).

Vitamins A, C, and E are known to affect fecundity of fish. The quality of the feed, especially the vitamin content, becomes more important as the females get older. For example, a-tocopherol or vitamin E is an essential substance for growth and reproduction of fish (Tokuda *et al.*, 2000). A deficiency of tocopherol leads to an inferior state of development of carp ovaries, resulting in increased moisture content, and reduced fat and protein content of the ovaries (Steffens, 1989), which in turn has a negative effect on the quality of the larvae produced. In ayu (*Plecoglossus altevelis*) for example, a reduced alpha-tocopherol level in the broodstock diet caused low survival rates of egg to eyed stage and hatching (Takeuchi, *et al.,* 1981), and caused reduced sexual coloration and reproductive activity in Nile tilapia (Schimittou, 1993).

Vitamin E (α-tocopherol) has been transported and preserved more positively in the gonad during the reproduction period. During maturity serum a-tocopherol had partly combined with the vitellogenin-like parts that diminished after the spawning period of Japanese flounder (Tokuda *et al.*, 2000). In addition, Izquierdo *et al.*, (2001) also have reported an increase in dietary a-tocopherol level up to 125 mg/kg resulted in an improvement in fecundity of gill-head seabream as expressed by the total number of eggs produced/female and egg viability.

A dietary supplement of ascorbic acid or vitamin C has positive effects on the reproductive performance in various fish species (Eskalinen, 1989). It has been suggested that supplementation of ascorbic acid (1250 mg of ascorbic acid per kg of dry diet) improves the hatchability of egg, and the condition and survival rate of fry (Soliman *et al.*, 1986). Although Furuita *et al.*, (2001) reported that feeding broodstock with a higher level of vitamin A increases the vitamin A content in eggs but does not affect egg quality of Japanese flounder, *Paralichthys olivaceus*, because excess dietary vitamin A was stored mainly in the broodstock liver.

The other component in fish diet is mineral. Minerals are needed by animals to maintain many of their metabolic processes and provide materials for major structural elements such as the skeleton. Minerals required for normal metabolism can be divided into two groups, major and trace minerals. Major minerals are required in large quantities and these include calcium, phosphorus, magnesium, sodium, potassium, chlorine, and sulphur. Trace minerals are those required small quantities and include iron, iodine, manganese, copper, cobalt, zinc, selenium, molybdenum, fluorine, alumanium, nickel, vanadium, silicon, tin and chromium (De Silva and Anderson, 1995).

Calcium and phosphorus are important constituents of skeletal material. Copper, manganese, cobalt, zinc, and selenium have a role in metabolic functions, iron is a component of the respiratory pigment haemoglobin, and iodine is required for the production of the thyroid hormone (Jobling, 1995).

Fish can absorb part of the required minerals directly from the water through their gills or even through their entire body surface, and the rate of mineral absorption varies among fish species and with variations in environmental factors such as the mineral concentration in the water, water temperature, pH etc. (Hepher, 1988). To date, the effects of minerals on the reproductive performance of fish have not been studied. However the role of minerals on reproduction of terrestrial animal have been evaluated by Nurhan *et al.*, (2002) and reported that supplemental chromium of 400 μg/kg of diet, and zinc of 30 mg/kg or combinations of 400 μg of Cr plus and Cr or 30 mg of Zn/kg of hen diets increased egg production and egg weight compared to control.

BROODFISH

The condition of female broodfish is another factor affecting the reproductive performance, eggs and larvae quality of fishes. Generally, fish fecundity and egg size increase by increasing broodfish size (Buckley *et al*., 1991 and Bromage *et al*., 1990), but the egg size may vary from one spawning to another, and the number of eggs contained in a specific volume may also be different (Carrillo *et al*., 2000; Jonsson and Jonsson, 1999). This result is supported by Kazakov (1981), and Morita and Takashima, (1998) who reported that egg size of rainbow trout, Atlantic salmon and white-spotted charr (*Salvelinus leucomaenis)* increased by increasing the age and size of females. A similar result was found in the Nile tilapia, *Oreochromis niloticus* (Gunasekera *et al*., 1996b), *Tilapia zillii,* (Coward and Bromage, 1999), and in white-spotted charr (Morita and Takashima,1998). Morita, *et al.,* (1999) also reported that egg size was strongly associated with broodfish growth history, however its association with egg number was not established.

In addition, Bromage *et al*., (1990) reported that fecundity, egg size, total egg volume of rainbow trout increased by increasing fish size, whereas relative fecundity decreased as fish get larger. A positive relationship between broodfish size, eggs and larval viability was also found in Australian bass (Harris, 1986) and Iceland cod (Marteinsdottir and Steinarsson, 1998). However, the relationship between the size of ripe eggs and fish size remains unknown. In haddock, *Melanogrammus aeglefinuse* for example, a significant relationship between the length of female brood fish and egg diameter was observed for the smaller 2-3 years old broodfish, but not for the larger fish (4-8 years old) (Hislop, 1988).

Lastly, it is a fact that females producing large eggs were limited to producing fewer eggs. Big eggs generally, produce larger larvae at hatching, which may have a positive influence on the individual fish in terms of resistance to starvation or other environmental challenges.

ENVIRONMENTAL FACTORS

Multiple environmental factors are often associated with gonad maturation and egg quality of the fish, especially in egg sizes (Chamber, 1997). Environmental factors regulate the hormone activity of the fish, thus affecting egg quality (Asturiano *et al*., 2000), indicating that the environment and hormones act both indirectly and directly, respective. A correlation between the annual breeding and testicular androgens have been reviewed by Liley and Stacey (1983) in numerous species of teleost such as stickleback, Atlantic salmon, gold fish, plaice, brown and rainbow trout, and striped mullet, and they found at least three environmental factors; season, temperature and salinity that influence egg size of fish.

In teleosts, temperate zone, highly predictable correlation is often observed for seasonal and reproductive cycle. In tropical zones, seasonal changes of environment are less extreme, and many fishes exhibit extended or continuous reproductive pattern (Redding and Patino, 1993). In temperate marine fishes, spawning occurs throughout the years. It has been found that water quality parameters such as dissolved oxygen, pH, salinity, temperature, nitrite are major factors affecting seed production of tilapias (Little *et al.*, 2000).

Water temperature and salinity vary seasonally, annually and spatially in temperate marine habitat. Water temperature and photoperiod are the dominant physical variable defining seasonally in these systems, and water temperature also varies strongly along latitudinal and depth gradients. Seasonal variation in salinity can also be substantial in near shore and estuarine habitats, reflecting seasonal fluxes in freshwater inflow, but the dominant salinity gradient is associated with the transition between freshwater and saltwater in estuaries (Chamber, 1997). In Atlantic cod *Godus marhua* for example, reduction in day length in terms of photoperiods is a vital environmental signal regulating the maturation and spawning, and sexual maturation delayed (Hemre *et al.*, 2002).

Water temperature which varies significantly throughout the year influences the relative fecundity in Baltic cod (Kraus, *et al.*, 2000). Temperature has been known as a factor affecting reproduction and metabolism of fish. Furthermore, temperature and photoperiod also affect the daily cycle of GtH in female gold fish (Hontela and Peter reviewed by Peter, 1983).

Generally, reproduction and metabolic rates of fish are slower at low temperatures, though it varies from one species to others. For example, Nile tilapia reproduction is slow at temperatures of 21 to 24°C and increases in frequency above 25°C up to 30°C (Popma and Lovshin, 1996), and in female sea bass, oocyte development is aborted and did not reach full maturation at temperatures below 10°C during the main period of gonad development (Pawson *et al.*, 2000).

However, it is reported that salinity rather than temperature plays a vital role in the reproduction performance in marine fish such as Atlantic cod, whereby the egg quality of captive Atlantic cod varies even at constant temperature (Kjesbu *et al.*, 1992).

Most of the studies suggest that salinity and temperature affect on egg size most during oogenesis (Chamber, 1997). As for temperature, the optimum level of salinity differs from one species to another.

For example, *Oreochromiss mossambicus* can reproduce at 35-49 ppt while *Oreochromiss aureus* and Tilapia zilli do not reproduce at all in sea water while *Oreochromiss niloticus* cease reproduction altogether at salinities higher that 30 ppt (Watanabe, 1985). Studies by Yeheskel and Avtalion, (1986) showed that fertility of *Oreochromiss niloticus* decreased from 94% to 26% by increasing salinities from 0.00 to 1.00 ppt, but fertility increased from 17% to 91% when pH increased from 4.5 to 9.0, while the spawning and total hatching rate of grey mullet, *Mugil cephalus* L was highest at 30 ppt (Lee and Menu, 1981).

EFFECT OF PROTEIN ON EGGS AND BODY COMPOSITIONS OF BROODSTOCK

Research on the dietary protein influence on egg and body composition of fish brood stock is still limited compared to the information available on dietary protein requirement for larvae and grow-out fish. Alhafedh *et al.* (1999) reported that the protein content of diet significantly influenced the protein content of the fish body, in that high dietary protein levels (40 to 45%) resulted in higher muscle protein content than the fish fed low and medium (25-35%) protein diets. They also reported that lipid content decreased by increasing dietary protein level. In addition, Gunasekera *et al.,* (1996b) has also found that protein content in eggs maintained on a 35% protein diet was significantly higher than those maintained on a 10% and 20% dietary protein level. In contrast, different dietary protein levels did not appear to influence egg protein content in European sea bass (Cerda *et al.,* 1994) and in red sea bream (Watanabe *at al.,* 1985).

Robinson and Li (1999) reported that visceral and fillet fat of channel catfish decreased by increasing the dietary protein level. Fish fed a 24% protein diet had higher visceral fat and fillet fat than those fed the 28% or 32% protein diet. Fattiness in channel catfish may be related to a number of factors, including sex, size, strain and age. Generally, there is a direct correlation between the DE/P ratio and fattiness in catfish (Robinson and Robinette, 1994). Robinson and Jackson (1991) reported that an increase in muscle fat was observed in channel catfish fed a feed containing 26% protein (11.1kcal DE/g protein) as compared to fish fed a 32% protein feed but with a lower energy content (9.0 kcal DE/g protein) or fish fed a 28% protein feed (10.4 kcal DE/g protein). Similar results were found by Li and Lovell (1992) that fish fed a low protein feed had a higher percentage muscle fat. Carcass moisture and total lipid after the feeding trial did not differ, and body protein increased with increasing dietary protein, but body protein of the control larvae was similar to that of larvae given the 60% protein diet (Eguia, *et al.*, 2000).

CONCLUSIONS

There are many factors have been identified as factor influencing egg quality and reproductive performance of fish female broodstock such as environment, broodfish condition and nutrition in term of protein, lipid, carbohydrate, vitamin and mineral. Although, nutrition especially protein, vitamin A, C and E are main factors that influencing egg quality and reproductive performance of fish directly and indirectly. In term of environment factor, temperature and salinity play a vital role in gonadal development of fish. In addition, body composition of fish and egg composition were influenced by composition of the diet.

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